Implementation of a Dog Tracking Device and Positioning System using GSM Technology with Android Map Application

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APPROVAL SHEET

This is to certify that we have supervised the preparation of and read the thesis paper prepared by **Ma. Teresa O. Arroyo, Eva Rachel A. Retuya and Mimi Jossa M. Rollan** entitled **Implementation of a Dog Tracking Device and Positioning System using GSM Technology with Android Map Application** and that the said paper has been submitted for final examination by the Oral Examination Committee.

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ABSTRACT

Dogs as a common pet are known as man's best friend and in most cases, an extended family member. When accidentally left unattended, dogs end up astray when they wander off from their homes. The goal of this research is to develop a portable tracking device without utilizing GPS and instead relying only on GSM technology. The device is capable of approximating the general location of the dog through use of Cell-ID method with addition of one neighboring cell. The researchers will also develop an application based on the android platform to be used in querying the location of the device. Findings from the measurements will help evaluate whether the proposed method is sufficient for location tracking without relying on GPS.

Keywords: animal tracking, GSM, triangulation, trilateration, Cell-ID positioning

Chapter 1

INTRODUCTION

In the United States alone, the number of pets entering shelters per year was estimated to be between 5 to 7 million (Weiss, 2012). Given the number, pets are lost from their homes or end up getting abandoned due to owner neglect. These abandoned and/or lost pets end up fighting for their survival on the streets and the possibility of being found by their respective owners decrease as time passes by. Being the most common pet, dogs are on top of the list of lost pets. Lost dogs usually end up astray, getting hit by vehicles, getting infected by diseases from other stray animals; or worse, getting butchered by dog-eaters. Stray dogs also have a high reproduction rate which may endanger the public since the said animal is classified as a source of rabies - a deadly disease that can be passed on humans commonly by a bite from an infected animal. As such, stray animals are being caught by authorities where an average of 200 dogs is euthanized every week at city pounds in the Philippines. The use of tracking devices apart from identification tags has been an option in the recent years to prevent incidentally pet loss. On the other hand, the GPS technology as means of tracking is rife with imperfections which include power management, implementation cost and satellite visibility around obstructions. The researchers are looking into the development of a tracking device without relying on GPS but instead deploy a method incorporating GSM technology as means of all-in-one device not only for communication but for tracking as well.

Animal tracking is existent for years, with most of the endeavor being applied to wildlife monitoring. Researches in the area often use one or a combination of RFID, GPS, and sensor networks to carry out tracking, identification and assessment of activity of the animal. At most, several researches use RFID technology as it was versatile for both identification and tracking purposes with a recent study based on passive UHF RFIDs in accordance to the journal of L. Catarinucci et al. entitled "An Innovative Animals Tracking System based on Passive UHF RFID Technology". Another recent study entitled "Animal Situation Tracking Service Using RFID, GPS and Sensors" by Kim, D.H. et al., involves a more complex approach which is to implement wireless sensor networks for monitoring state and activity complete with integration of GPS for tracking and RFID for identification purposes.

There are a lot of studies regarding RFID and GPS; it varies from article to article where some are applied to car navigation systems, location-based/dependent applications, and other numerous uses among them which wildlife tracking benefits the same. On the other hand, wireless sensor networks are often applied for monitoring environment conditions. Previous researches show domesticated animals i.e. farm-bred and pets have little or no emphasis with regards to animal tracking. Thus, researchers opt to focus on this domestic setting, specifically companion pets. The researchers also intend to examine whether the GSM technology is a viable replacement for GPS given the accuracy measurements. The deployment of GSM technology as opposed to GPS for tracking purposes will absolutely mitigate energy consumption and at the same time bring down costs as it is widely available requiring no special hardware and eventually will lessen lost pet cases.

To address the problem with regards to lost pets specifically dogs that is the common companion pet, the researchers intend to track the location of the dog using only the widely-available GSM technology. To realize such concept, the researchers will build a device to be attached to the dog and that it will not rely on GPS or any other method of location approximation. The device must be interfaced in such a way for it to receive request location, scan necessary data to aid location approximation and send that data to a mobile application that uses the android platform. The researchers will develop the said android application with the intent to analyze the data gathered by the device attached to the dog to produce relevant coordinates. Lastly, the overall system must be able to pinpoint the approximate current location of the dog on a map.

The researchers understand the need to secure safety and well-being of companion dogs by lessening the chance of them ending up astray and homeless in the long run as well as avert possible cases of rabies contraction coming from stray dogs. Not only that, but also the development of the tracking method. The significance lies on the utilization of GSM technology which is commonly used for communication purposes. Here, the researchers employed a common technique that base the approximate location of the device on the location of the tower. From there, further accuracy can be achieved by utilizing neighboring towers and computing the average coordinate between the towers. Therefore, the system may be compared to GPS in such a way that it draws strength by negating the latter's imperfections but at the price of sacrificing a little accuracy. Deployment of GSM as means of location tracking is easy since it is widely available not to mention cheaper than GPS. Also, it is not as power-hungry and will last longer on continuous use. There's also the fact that GPS does not work in an indoor

setting due to obstructions that limit satellite visibility – a known drawback and limitation. However, the proposed system based on GSM can be used anywhere provided the device has signal and is powered on.

In this respect, the study will cover a device capable of being queried of its current location, scan necessary data to be used for location approximation and then sending the data back for analysis on the android application. The proposed device is attached to the dog using a customized body strap and is powered using two cellular mobile batteries. The study however will not cover extensive explanation and detail about databases pertaining to cellular tower locations. The system will not cover populating of new data into these databases and is not capable of *real-time tracking*. It will rest upon the discretion of the user whether to provide additional cellular tower locations for accuracy improvements. At the time of writing, the researchers only focused on a small area to facilitate test results. Loss of signal due to limited coverage areas will be neglected.

Chapter 2

REVIEW OF RELATED LITERATURE

This chapter outlines the primary concepts the study is concerned particularly the relevant keywords, technology used and the approaches other researchers in the same field employed to accomplish a similar goal.

Animal Tracking

Several research and applications had existed offering a variety of methods to carry out animal tracking. According to the journal entitled "An Innovative Animals Tracking System based on Passive UHF RFID Technology" by Catarinucci et al., a tracking system was designed for small animals through utilization of passive NF UHF RFID technology. The working prototype involved 6 built-in-lab NF antennas tested in a laboratory environment where it has been said that the results are impressive since RFID is best used in closely-confined spaces. Apart from RFID, other methods employ wireless sensor networks such as J. Karlsson et al's "Tracking and Identification of Animals for a Digital Zoo" and the "GPS-Less Animal Tracking System" by A. Joshi et al. There are also several studies that utilize GPS where RFID served other purpose like identification of animal concerned. According to S.H. Kim et al's "Animal Situation Tracking Service using RFID, GPS and Sensors" and "An advanced Low-Cost, GPS-Based Animal Tracking System" of P.E. Clark et al, the proposed systems are capable of providing real-time animal information apart from location. RFID and WSNs offer robust nearby

tracking capabilities whereas global and/or extensive location tracking is covered by GPS technology.

Given the size and feature of household pets, it is best to monitor location whereabouts through GPS. Development of lightweight GPS-tagging device – the work of M.R. Recio et al. was used to track feral cats which led to the advent of GPS collar-based devices. These devices are functional in tracking wildlife animals as exhibited by the paper "wildCENSE: GPS Based Animal Tracking System" where the concerned animal is the swamp deer. (Jain, 2011). On the other hand, domestic animals (such as cattle) were the subject of a study by Handcock et al in their work, "Monitoring Animal Behavior and Environmental Interactions using Wireless Sensor Networks, GPS Collars and Satellite Remote Sensing". Apart from these, a VHF collar integrated antenna was also developed and tested on dogs (Yoo, 2011).

A closely related work to this proposal is accomplished by Chakchai So-In et al. entitled "Mobile Animal Tracking Systems Using Light Sensor for Efficient Power and Cost Saving Motion Detection", providing an avenue for open architecture of animal tracking systems through use of easy-to-access Arduino board coupled with various carefully-interfaced sensors. The work utilizes the widely-accessible Google MAP API functionalities where location and sensor data are sent over GSM networks but is restricted to Android-based phones only. The advantage of this proposal is that it does not use GPS in locating the animal but instead utilizes the GSM technology to full potential by also allowing it to be used in location awareness apart from the common communication use.

Pet Lost/Abandoned Statistics

According to the article of E. Weiss et al entitled "Frequency of Lost Dogs and Cats in the United States and the Methods Used to Locate Them", 14% of dogs owned in the US gets lost at least once during a five-year period and the 7% were never reunited with their owners. The study conducted survey, data collection and statistical analysis to determine frequency of loss and chances of reuniting with respective owners.

Using the data gathered above to make some estimates of the number of lost pets in the last 5 years yielded 10,948,000 dogs lost nationally while 766,360 were not reunited with their owners out of 78.2 million dogs owned across US.

Table 2.1 shows the data relating to the frequency of dogs getting lost, type of ID worn during the most recent episode and the methods used to find the pet. The survey reflects participants from all states except Alaska, Delaware, Hawaii and Wyoming.

Table 2.1 A national survey of 1,014 households owning dogs in the past five years

Question	Number of Dogs	Percentage of Dogs
Has your pet ever become lost in the past five years?		
Yes	110	14(11-16)
No	705	87(84-89)
Total	815	100
Refused	1	
Don't Know	0	
If yes, how many times was the pet lost?		
1 time	52	49 (39-58)
2-5 times	38	36 (27-45)
6-10 times	12	11 (6-19)
More than 10 times	5	6 (2-11)
Total	107	100
Don't Know	3	

Table 2.1 *Cont.*

Question	Number of Dogs	Percentage of Dogs
Which of the following was your pet wearing the last time he/she was lost? (more than one could be worn) n= dog sample size		
Wearing a collar (n=109)	98	90 (83-95)
Wearing a rabies tag (n=106)	74	70 (50-78)
Wearing a license (n=104)	60	58 (48-67)
Wearing a personalized ID tag with phone number (n=109)	67	61 (52-71)
Had a microchip (n=103)	25	24 (16-34)
No rabies, license or ID tag or microchip (n=101)	11	11 (6-19)
Did you find your pet?		
Yes	101	93 (86-97)
No	8	7 (3-14)
Total	109	100
Don't know	1	
Refused	0	
What was the primary method used to find the pet (when successful)?		
I found my pet by searching my neighborhood	49	49 (28-59)
My pet returned on its own	20	20 (13-29)
I was contacted because of a tag my pet was wearing/my pet's microchip	15	15 (9-23)
Neighbor brought pet home	7	7 (3-14)
I found my pet by visiting/contacting animal control	6	6 (2-12)
Other	4	4 (1-10)
Total	101	100
Refused		
What methods were used to attempt to find pet (unsuccessful)? more than one answer was possible		
Waited for pet to come home	6	75 (35-97)
Searched neighborhood	6	75 (35-97)
Visited shelter	6	75 (35-97)
Hung posters	4	50 (16-84)
Ad in paper	4	50 (16-84)
Posted online	4	50 (16-84)
Called veterinary or other professionals	3	38
Other	0	0
Refused	0	

Global System for Mobile Communication (GSM)

Based from the book entitled "MOBILE MESSAGING, Technologies and Services SMS, EMS and MMS, Second Edition" by G. Le Bodic, GSM is regarded the most pivotal communication system due to its ability to provide communication between people anywhere and at any time. It offers robust services such as voice communication, MMS, EMS, SMS and GPRS with the Short Message Service being the most popular service. The said service allows subscribers to send and receive short text messages.

According to the journal of Okatan et al, entitled "Micro-Controller Based Vehicle Tracking System via use of GPS and GSM", the capacity of SMS convey up to 160B (bytes) of information received or sent from a mobile phone to another. Cellular devices employ a diverse method in sending electronic messages. Basically, the electronic message in PDU format is converted into text format and afterwards, the originator adds parameters to the modified string then is processed by Short Message Service Centers referred to SMSC.

Based from the dissertation of Mattsson O. entitled "Positioning of a Cellular Phone using the SIM", GSM architecture is composed of various distinct components, divergent to three main sections. Firstly, the Mobile Station consisting of mobile equipment and the Subscriber Identity Module which in other words is the phone possessed by the person capable of placing and receiving calls. This is followed by the Base Station System further comprised of the Base Transceiver and Controller responsible for connecting the MS to the network and entrusted of transmitting and receiving. Lastly, the Switching System that manages the interaction between subscribers and incorporates structured data crucial for subscriber data and mobility management.

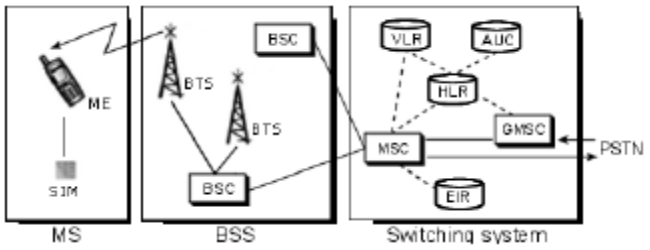

Figure 2.1 GSM Architecture
Source: Mattsson, 2001 (Positioning of a Cellular Phone using the SIM)

GSM technology is primarily utilized in communication. One application of this is the "Automatic Ambulance Rescue System" from researchers Athavan, et al. In this work, nodes made up of traffic junctions are deployed with its own GSM module and microcontroller embedded. The GPS system determines the location of the vehicle situated on an accident spot (latitude and the longitude) and sends the information to the GSM module. This module in turn coordinates to the main server by passing retrieved data and whose GSM number is already known as an emergency number.

Apart from communication, location awareness both indoor and outdoor can be carried through GSM. The journal entitled "Are GSM Phones the Solution for Localization?" written by A. Varshavsky et al argued that localization based on GSM technology is sufficient enough in coverage and fidelity for a wide extent of applications in an outdoor, indoor and place-detection setting. The study presented results showing GSM is rather effective in achieving 2 to 5 meters of median error in room-level tracking within a building and 70 up to 200 meters of the same error outside.

Also, Mattsson O. (2001) who wrote "Positioning of a Cellular Phone using the SIM", obtaining the position through GSM technology can be carried out using different methods. These include the Cell of Origin referred to as Cell-ID method, several timing

techniques, Angle of Arrival and Received Signal Strength. Cell of Origin is plain and inexpensive procedure to utilize due to non-requirement of any alteration in the handset or network. The method ascertains the cell identification of the tower the MS is connected from which has a fix position and that location approximation is determined by the position of the said tower. Timing Advance on the other hand is used to provide a more accurate position fix for the cell-ID method where it functions in synchronizing signals between the mobile phone and the cell tower it connects from. Together with COO, it can narrow down the radius around the BTS to an approximate 550m wide arc.

Moreover, Mattsson O. (2001) stated on his dissertation "Positioning of a Cellular Phone using the SIM", TOA method of approximation comes from quantifying signals transmitted by the mobile phone to three or more cellular tower where the received signal is handed towards a Location Measurement Unit or LMU which in turn determines time spent from which the signal moves between the phone and the tower. Measurements are then used to calculate a circle around the BTS and the intersection of the circles coming from at least 3 BTS determines the approximate location of the MS. On another hand, TDOA is a variation of TOA where it is used when the signal's time sent is indeterminate.

According to "Location Technologies for GSM" by Brida, E-OTD works in a similar fashion as TDOA but in the other direction; it is based on the MS measuring the arrival time difference between the bursts of nearby BTSs in GSM. This method requires modifications to the mobile station and that at least three BTS units are required to calculate an intersection.

The AOA method requires that BTSs to be equipped with antennas in order to provide measurement of angles of arrival for signals transmitted by the MS. Assuming such measurements are available, the intersection of the lines defined by angles of arrival is the supposed location of the MS. It is outlined in the paper "Overview of Location Techniques" that Received Signal Strength requires a proper propagation model i.e. Hata model to convert RSS data into distances from the respective neighboring BSs. Standard trilateration techniques determine the position of MS.

Triangulation and Trilateration

Using the triangulation principle, S. Chao et al (2010) proposed a new method of frequency planning for new cells under GSM network. The information carried out through this new cell planning can be utilized in performing localization due to placement overhead of the concerned cells. (Chao, 2010).

Triangulation and/or trilateration require at least three cells in principle. A study conducted by Q.R. Mahfuz et al for vehicle tracking utilized cell information such as timing advance gathered from three different cells to calculate the vehicle's exact location. The reported accuracy of the study lies within a circle of 200-meter radius. (Parvez, 2010).

Cell-ID Positioning

The main highlight of Cell-ID positioning is its capability to localize any GSM mobile subscriber where location accuracy depends on size and density of network cells

and that no software or hardware changes are needed by both the network and the mobile phone.

I.Gregor et al (2008) produced a prototype named SS7Tracker based on GSM Cell-ID Positioning. (Novak, 2008). The said prototype is an active, non-intrusive networked-based location tracking where periodic querying of the network about the location of concerned devices is performed unlike passive tracking methods where location information is only generated when there is direct contact between a mobile phone and the GSM network.

The Cell-ID method of location approximation is entirely based on the location of the serving BTS and its surrounding radius meaning, accuracy isn't as par with GPS. However, several studies tried to improve this method by introducing the Enhanced Cell-ID method. M.M. Petrovic et al in particular proposed a better positioning technique in the journal entitled "Enhanced Cell-ID+ TA GSM Positioning Technique" where the said technique utilized timing advance variables from all apparent BTSs in the area combined with the empirically modeled behavior of timing advance and an algorithm for evaluating the position of MS. The location error with the proposed system is found at 135m of 67% accuracy and 245m of 95% accuracy compared to Cell-ID's 283m, 67% accuracy.

Haversine Formula

According to the amateur astronomy magazine Sky & Telescope under the article "Virtues of the Haversine" published by Roger Sinnott, haversine was used in navigation. The haversine formula is a very accurate way of computing distances

between two points on the surface of a sphere using the latitude and longitude of the two points. The haversine formula is a re-formulation of the spherical law of cosines, but the formulation in terms of haversines is more useful for small angles and distances. The haversine formula could yield accurate results without requiring the computationally expensive operations of squares and square roots. Moreover, the said magazine was singing the praises of the haversine formula, which is not only useful for terrestrial navigation but also for celestial calculations.

Based from the journal "Effective Technique for Allocating Servers to Support Cloud using GPS and GIS" by Ayad Ghany Ismaeel, the algorithm of haversine formula was used to compute the nearest/distance between the source server and the idle server to support cloud in a more effective cost.

Moreover, the haversine formula was also used to calculate the minimum ambulance travelling distance between longitude and latitude in kilometres and miles in the journal of Noraimi Azlin Mohd Nordin,et al entitled "Finding Shortest Path of the Ambulance Routing: Interface of A* Algorithm using C# Programming."

Chapter 3

Implementation of a Dog Tracking Device and Positioning System using GSM Technology with Android Map Application

Abstract

Dogs as a common pet are known as man's best friend and in most cases, an extended family member. When accidentally left unattended, dogs end up astray when they wander off from their homes. The goal of this research is to develop a portable tracking device without utilizing GPS and instead relying only on GSM technology. The device is capable of approximating the general location of the dog through use of Cell-ID method with addition of one neighboring cell. The researchers will also develop an application based on the android platform to be used in querying the location of the device. Findings from the measurements will help evaluate whether the proposed method is sufficient for location tracking without relying on GPS.

Keywords: animal tracking, GSM, triangulation, trilateration, Cell-ID positioning

Introduction

In the United States alone, the number of pets entering shelters per year was estimated to be between 5 to 7 million (Weiss, 2012). Given the number, pets are lost from their homes or end up getting abandoned due to owner neglect. These abandoned and/or lost pets end up fighting for their survival on the streets and the possibility of being found by their respective owners decrease as time passes by. Being the most common pet, dogs are on top of the list of lost pets. Lost dogs usually end up astray, getting hit by vehicles, getting infected by diseases from other stray animals; or worse, getting butchered by dog-eaters. Stray dogs also have a high reproduction rate which may endanger the public since the said animal is classified as a source of rabies - a deadly

disease that can be passed onto humans commonly by a bite from an infected animal. As such, stray animals are being caught by authorities where an average of 200 dogs is euthanized every week at city pounds in the Philippines. The use of tracking devices apart from identification tags has been an option in the recent years to prevent incidentally pet loss. On the other hand, the GPS technology as means of tracking is rife with imperfections which include power management, implementation cost and satellite visibility around obstructions. The researchers are looking into the development of a tracking device without relying on GPS but instead deploy a method incorporating GSM technology as means of all-in-one device not only for communication but for tracking as well.

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same. On the other hand, wireless sensor networks are often applied for monitoring environment conditions. Previous researches show domesticated animals i.e. farm-bred and pets have little or no emphasis with regards to animal tracking. Thus, researchers opt to focus on this domestic setting, specifically companion pets. The researchers also intend to examine whether the GSM technology is a viable replacement for GPS given the accuracy measurements. The deployment of GSM technology as opposed to GPS for tracking purposes will absolutely mitigate energy consumption and at the same time bring down costs as it is widely available requiring no special hardware and eventually will lessen lost pet cases.

To address the problem with regards to lost pets specifically dogs that is the common companion pet, the researchers intend to track the location of the dog using only the widely-available GSM technology. To realize such concept, the researchers will build a device to be attached to the dog and that it will not rely on GPS or any other method of location approximation. The device must be interfaced in such a way for it to receive request location, scan necessary data to aid location approximation and send that data to a mobile application that uses the android platform. The researchers will develop the said android application with the intent to analyze the data gathered by the device attached to the dog to produce relevant coordinates. Lastly, the overall system must be able to pinpoint the approximate current location of the dog on a map.

The researchers understand the need to secure safety and well-being of companion dogs by lessening the chance of them ending up astray and homeless in the long run as well as avert possible cases of rabies contraction coming from stray dogs. Not only that, but also the development of the tracking method. The significance lies on the

utilization of GSM technology which is commonly used for communication purposes. Here, the researchers employed a common technique that base the approximate location of the device on the location of the tower. From there, further accuracy can be achieved by utilizing neighboring towers and computing the average coordinate between the towers. Therefore, the system may be compared to GPS in such a way that it draws strength by negating the latter's imperfections but at the price of sacrificing a little accuracy. Deployment of GSM as means of location tracking is easy since it is widely available not to mention cheaper than GPS. Also, it is not as power-hungry and will last longer on continuous use. There's also the fact that GPS does not work in an indoor setting due to obstructions that limit satellite visibility – a known drawback and limitation. However, the proposed system based on GSM can be used anywhere provided the device has signal and is powered on.

In this respect, the study will cover a device capable of being queried of its current location, scan necessary data to be used for location approximation and then sending the data back for analysis on the android application. The proposed device is attached to the dog using a customized body strap and is powered using two cellular mobile batteries. The study however will not cover extensive explanation and detail about databases pertaining to cellular tower locations. The system will not cover populating of new data into these databases and is not capable of *real-time* tracking. It will rest upon the discretion of the user whether to provide additional cellular tower locations for accuracy improvements. At the time of writing, the researchers only focused on a small area to facilitate test results. Loss of signal due to limited coverage areas will be neglected.

Methodology

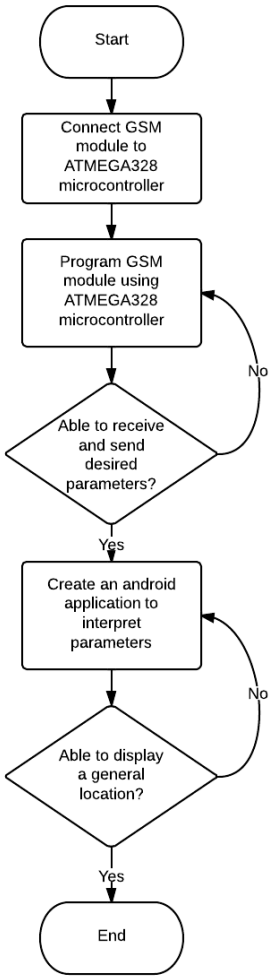
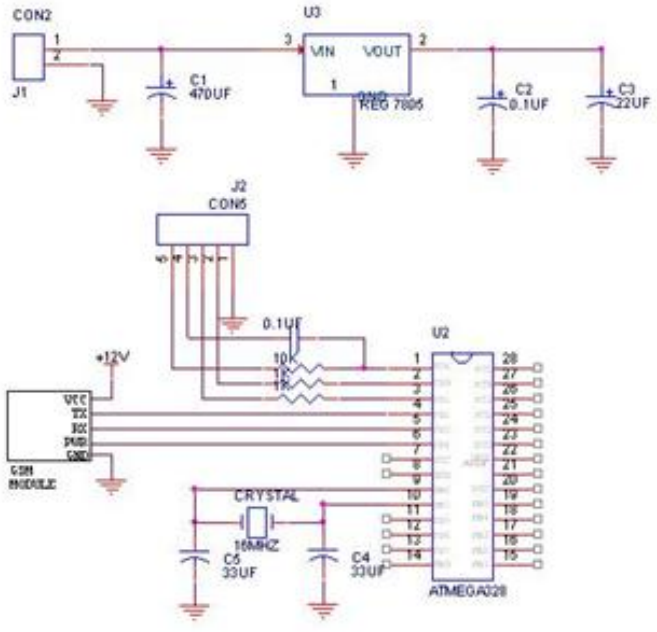


Figure 3.1 Conceptual Framework

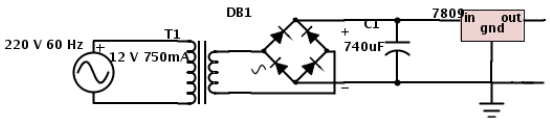
The Conceptual Framework of the study consists of two main parts. The first part is the gathering of information about the surrounding towers gathered by the AT command Engineering mode (AT+CENG) which displays parameters needed to identify cell towers such as Mobile Country Code, Mobile Network Code, Location Area Code, Cell ID, Absolute Radio Frequency Channel Number and Base Station Identity Code from the SIM900D GSM/GPRS module and ATMEGA328 microcontroller. These

parameters can be seen in the AT Commands Manual. The second part is the interpreting of the gathered information in an Android application via retrieval of related information from a database i.e. “opencellid” and in turn translates the data into GPS coordinates which Google Maps use to show the location in a map.

The first part consists of interfacing the ATMEGA328 microcontroller and the SIM900D GSM module. The GSM module was programmed using AT Commands while the microcontroller was programmed using Arduino language which is a C-like language. Both were programmed in Arduino IDE with the use of SoftwareSerial library and MsTimer2 library for the GSM module to be able to communicate with the microcontroller. The second part consists of the Android application which interprets data from the received SMS into longitude and latitude or GPS coordinates. The Android application was programmed in Basic4Android which uses JAVA programming language.



(a)



(b)

Figure 3.2 Schematic Diagram

In figure 3.2 (a), the ATMEGA328 microcontroller is connected to SIM900D GSM module, 16MHz crystal oscillator and to two serially connected 3.4 volt Li-Ion batteries which serve as the power supply of the device when in use. The microcontroller is also connected to UART for programming purposes. Figure 3.2 (b) is the schematic diagram of the provided charger for the device which is composed of a transformer, bridge diode, capacitor and a voltage regulator that has an output of 9 volts. It can also be used as an external source of power if applicable.

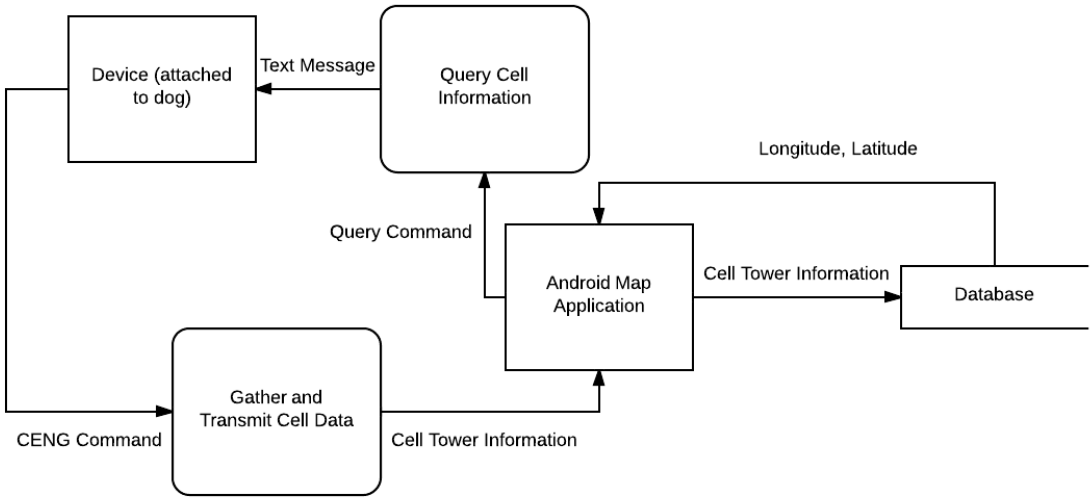
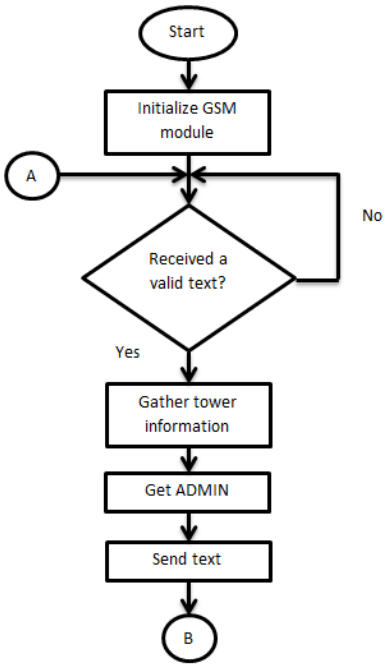
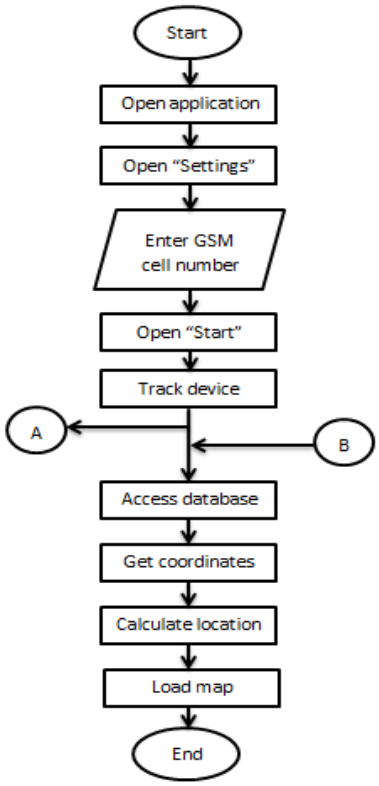


Figure 3.3 Data Flow Diagram



(a) Arduino



(b) Android

Figure 3.4 System Flowchart

The device being tracked (ATMEGA328 microcontroller and GSM module) is located at the back of the dog and the device that tracks (where the Android application is installed) is the client-side device. Both the devices should be active or turned on and must have prepaid load in order to communicate. The client-side device should also be connected to the internet for accessing the database and loading the map.

Using AT Commands, the GSM module was able to send and receive messages. All received messages are checked whether or not they comply with the correct format. The format of the message should be "TRACK" with no other characters and characters should be in upper case, otherwise it will be deleted and no further actions will be done. If the message was validated, the GSM module will gather information about the cell tower it is currently connected to as well as some information regarding the neighboring towers. This information will then be sent to the phonebook entry named ADMIN which is determined by the user before placing the SIM card into the device. The cell tower information included in the SMS are MCC, MNC, Cell ID, RSS, LAC, ARFCN, and BSIC, respectively, of the servicing tower denoted by "0" at the beginning of the message and the ARFCN, LAC and BSIC of the neighboring tower denoted by ":1", if a neighboring tower is available. The GSM module can only connect to 2G towers, thus 3G and 4G towers cannot be used in this study.

0_515_02_561a_-72_4f05_"0844_62:1_4f03_"0033_09

Figure 3.5 Sample Text Message

Upon receiving the text message from the device, the Android application will then access the database for the cell towers' GPS coordinates. The number of GPS coordinates generated may vary from the number of tower information received

depending if the towers were already added to the database. A single location will then be derived from the gathered coordinates which will be displayed in a map.

A mobile phone is only able to connect to one cell tower at a time. All the cell tower information mentioned above is available for only the said cell tower. For the neighboring towers, only limited information can be gathered.

Fingerprinting Process

Fingerprinting is the process of collection of data for the purpose of identification. This process is used by the researchers in population of cell tower information such as cell ID, LAC, ARFCN and BSIC, and their respective GPS coordinates in the database. Open-source and crowd-sourced database such as "opencellid.org" do not collect cell tower information aside from cell ID. This limits the researchers to resort in using only one tower. However, the database used in this research utilizes other cell tower information in recognizing the identity of neighboring towers.

Since the researchers used a new database, fingerprinting is a must. This process is done thoroughly in a specific area to assure the accuracy of the location of the towers.

Statistical Treatment of Data

$$H_0: \mu_2 \leqslant \mu_1$$

Null Hypothesis

(3.1)

$H_1: \mu_2 > \mu_1$

Alternative Hypothesis

(3.2)

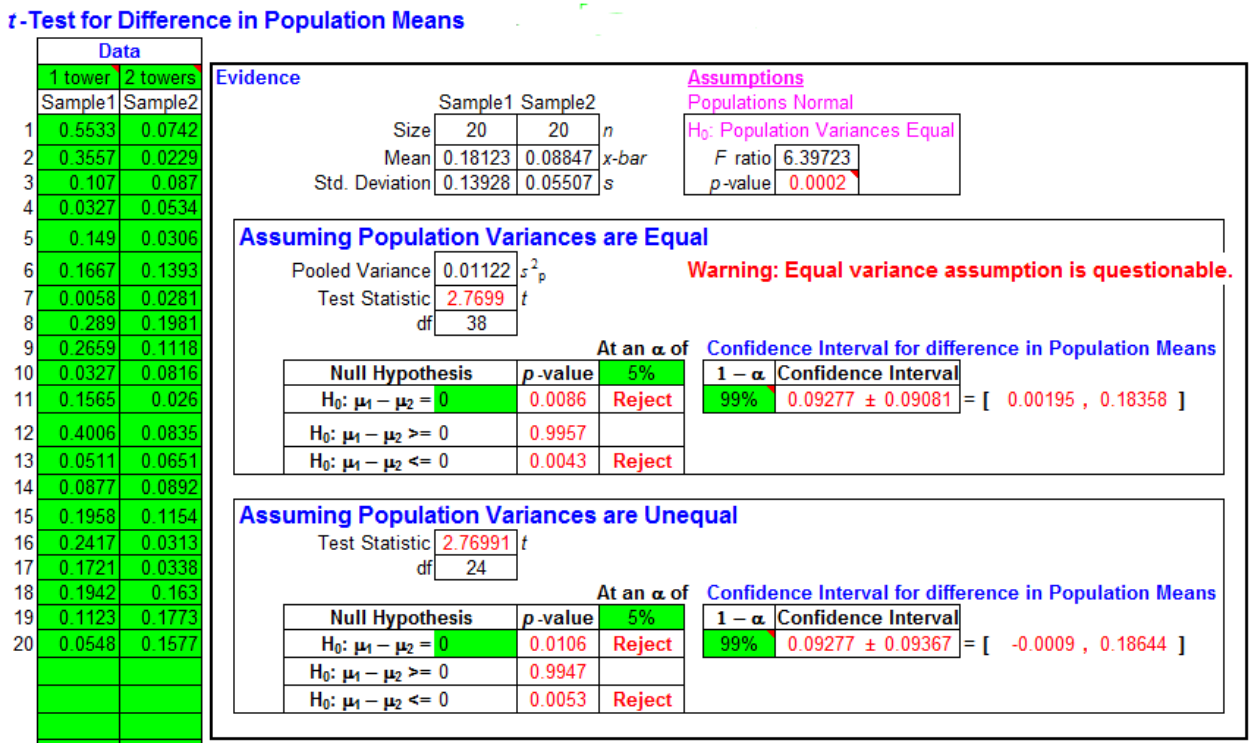
The null hypothesis states that the calculated distance or relative error of the device from the calculated location to the actual location is more accurate when utilizing two towers in generating the location of the device than that when using only a single tower. The alternative hypothesis on the other hand indicates that the results generated from a single tower are more accurate than those from two towers or both methods would yield the same accuracy.

Table 3.1 Common Interpretation of P-Values

P-value	Interpretation
$P < 0.01$	Very strong evidence against the hypothesis
$0.01 \leqslant P < 0.05$	moderate evidence against the hypothesis
$0.05 \leqslant P < 0.10$	suggestive evidence against the hypothesis
$0.10 \leqslant P$	little or no real evidence against the hypothesis

Using the critical value that can be found at Fig. 3.6, we note that the observed test statistic value is in the rejection region since $2.7699 < 2.845$. We thus accept the null hypothesis ($H_0: \mu_2 \leqslant \mu_1$) with a p-value of 0.99, and reject alternative hypothesis ($H_1: \mu_2 > \mu_1$) with a p-value of around 0.01 which shows very strong evidence against the said hypothesis. Therefore, we conclude that the null hypothesis with a p-value of 0.99 is an accepted hypothesis at the 5% level of significance. This is a very small p-value (compared to 5%), and thus we have a statistically significant result, i.e., very strong evidence accepting the null hypothesis.

We thus accept the null hypothesis at the 5% level. It appears that the difference in distance between using single tower and two towers, using two towers yields more accurate results.



t-Test for Difference in Population Means

	Data	
	1 tower	2 towers
	Sample1	Sample2
1	0.5533	0.0742
2	0.3557	0.0229
3	0.107	0.087
4	0.0327	0.0534
5	0.149	0.0306
6	0.1667	0.1393
7	0.0058	0.0281
8	0.289	0.1981
9	0.2659	0.1118
10	0.0327	0.0816
11	0.1565	0.026
12	0.4006	0.0835
13	0.0511	0.0651
14	0.0877	0.0892
15	0.1958	0.1154
16	0.2417	0.0313
17	0.1721	0.0338
18	0.1942	0.163
19	0.1123	0.1773
20	0.0548	0.1577

Evidence

	Sample1	Sample2	
Size	20	20	*n*
Mean	0.18123	0.08847	*x-bar*
Std. Deviation	0.13928	0.05507	*s*

Assumptions: Populations Normal

H_0: Population Variances Equal

F ratio 6.39723

p-value 0.0002

Assuming Population Variances are Equal

Pooled Variance 0.01122 s^2_p

Test Statistic 2.7699 *t*

df 38

Warning: Equal variance assumption is questionable.

Null Hypothesis	*p*-value	At an α of 5%
H_0: $\mu_1 - \mu_2 = 0$	0.0086	Reject
H_0: $\mu_1 - \mu_2 >= 0$	0.9957	
H_0: $\mu_1 - \mu_2 <= 0$	0.0043	Reject

Confidence Interval for difference in Population Means

1 − α	Confidence Interval
99%	0.09277 ± 0.09081 = [0.00195 , 0.18358]

Assuming Population Variances are Unequal

Test Statistic 2.76991 *t*

df 24

Null Hypothesis	*p*-value	At an α of 5%
H_0: $\mu_1 - \mu_2 = 0$	0.0106	Reject
H_0: $\mu_1 - \mu_2 >= 0$	0.9947	
H_0: $\mu_1 - \mu_2 <= 0$	0.0053	Reject

Confidence Interval for difference in Population Means

1 − α	Confidence Interval
99%	0.09277 ± 0.09367 = [-0.0009 , 0.18644]

Figure 3.6 t-Test for Difference in Population Means

Results and Discussion

The testing of the system was conducted at Intramuros, Manila. For testing purposes, the researchers have fingerprinted the area prior to the actual testing in order to ensure that the towers used are added to the database. Calculated GPS location is based from the system while Actual GPS location is based from the GPS location derived from Google Maps with the use of internet. The tests include locating the device using single tower and using two towers with the use of neighboring tower's GPS location.

Table 3.2 Tests Using a Single Tower

Trial	Calculated GPS location		Actual location		Relative
	Latitude	Longitude	Latitude	Longitude	Error (km)
1	14.59317	120.978695	14.588194	120.978695	0.5533
2	14.589525	120.978789	14.586532	120.977622	0.3557
3	14.588425	120.976161	14.587591	120.976657	0.1070
4	14.588425	120.976161	14.588547	120.975884	0.0327
5	14.589338	120.976448	14.58946	120.975069	0.1490
6	14.591835	120.973492	14.590457	120.974103	0.1667
7	14.59169	120.973039	14.591703	120.972987	0.0058
8	14.588425	120.976161	14.585826	120.97612	0.2890
9	14.589338	120.976448	14.587467	120.977987	0.2659
10	14.588635	120.977861	14.588817	120.977622	0.0327
11	14.588635	120.977861	14.589626	120.976828	0.1565
12	14.590553	120.97714	14.592637	120.974103	0.4006
13	14.589616	120.975614	14.590062	120.975498	0.0511
14	14.589616	120.975614	14.589211	120.976313	0.0877
15	14.589076	120.978671	14.58838	120.977	0.1958
16	14.588425	120.976161	14.589377	120.97818	0.2417
17	14.590553	120.97714	14.589377	120.97818	0.1721
18	14.589338	120.976448	14.59108	120.976571	0.1942
19	14.592469	120.975646	14.59272	120.976657	0.1123
20	14.592469	120.975646	14.592658	120.975176	0.0548
		Average			**0.1812**

Table 3.3 Tests Using Two Towers

Trial	Calculated GPS location		Actual location		Relative
	Latitude	Longitude	Latitude	Longitude	Error (km)
1	14.58886	120.9787	14.588194	120.978695	0.0742
2	14.58674	120.9777	14.586532	120.977622	0.0229
3	14.58811	120.9773	14.587591	120.976657	0.0870
4	14.58894	120.9762	14.588547	120.975884	0.0534
5	14.58954	120.9753	14.58946	120.975069	0.0306
6	14.59146	120.9749	14.590457	120.974103	0.1393
7	14.59177	120.9732	14.591703	120.972987	0.0281
8	14.58723	120.975	14.585826	120.97612	0.1981
9	14.58795	120.9771	14.587467	120.977987	0.1118
10	14.58862	120.9769	14.588817	120.977622	0.0816
11	14.58948	120.9766	14.589626	120.976828	0.0260
12	14.59255	120.9749	14.592637	120.974103	0.0835
13	14.5897	120.976	14.590062	120.975498	0.0651
14	14.58892	120.9771	14.589211	120.976313	0.0892
15	14.58895	120.9779	14.58838	120.977	0.1154

Table 3.3 *Cont.*

Trial	Calculated GPS location		Actual location		Relative Error (km)
	Latitude	Longitude	Latitude	Longitude	
16	14.58923	120.9784	14.589377	120.97818	0.0313
17	14.58945	120.9785	14.589377	120.97818	0.0338
18	14.59213	120.9776	14.59108	120.976571	0.1630
19	14.59228	120.9751	14.59272	120.976657	0.1773
20	14.59161	120.9762	14.592658	120.975176	0.1577
		Average			**0.0885**

Tables 3.2 and 3.3 show the calculated GPS locations based from the tower or towers that the device was connected to, the actual GPS location of the device based from Google maps, and the relative error or the distance of the two GPS locations in kilometers. In the event that the device has connected to only one tower, the calculated GPS location will be equal to the GPS location of the tower based on the database as shown in Table 3.2. On the other hand, when two towers are detected by the device, the calculated GPS location will be equal to the average or midpoint of the GPS locations of the two towers as seen on Table 3.3.

Interpretation of Results

In the event that only one tower information is gathered, the calculated GPS location will be equal to the GPS location of the tower away from the device. Whereas, if two tower information are gathered, the calculated GPS location will be equal to the two towers' GPS location divided by two.

The results are dependent on the sufficiency of available towers on the database. The results may also vary widely if the database is updated and approximate tower locations were adjusted.

For a single cell tower, the scope of the calculated location is illustrated in figure 3.5. The results may be closer to where the device is but a lot less accurate because the area covered by a single tower is located within a distance band of a cell tower circle.

For two cell towers, the scope of the calculated location is illustrated in figure 3.6. The results is more accurate than of that of the single tower though at times farther from the device because the area covered by two towers is located within a distance band of where two cell tower circles overlaps.

Table 3.1 shows that the GPS locations generated from a single tower range from 0.0058km to 0.5533km and have a mean value of 0.1812km; while Table 3.2 shows that the GPS locations generated from two towers range from 0.0229km to 0.1981km and have a mean value of 0.0885km. Thus, the number of cell towers located has an effect in the degree of accuracy of the device. Based from the testing done it proves that for the results from using two towers is almost twice more accurate than using single tower.

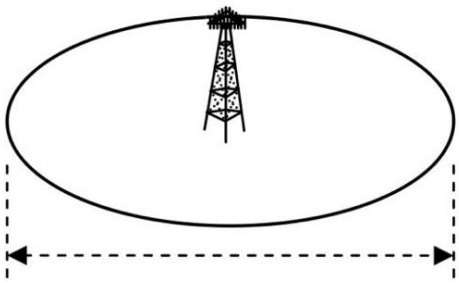


Figure 3.7 Illustration of Scope Tests Using a Single Tower
Source: Khalid, A. M. (2007) Location Aware System Using Mobile Station in GSM Network

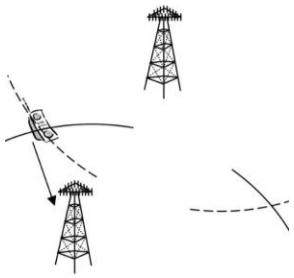


Figure 3.8 Illustration of Scope Tests Using Two Towers
Source: Khalid, A. M. (2007) Location Aware System Using Mobile Station in GSM Network

Chapter 4

CONCLUSION

A successful opportunity was developed for the GSM technology in terms of tracking animals (dog) which is mostly known to be used in communication. Based from the gathered data, the results are proven to be sufficient in tracking the said animal. Thus the researchers conclude that position tracking of the device with the use of GSM technology was a success. The device was able to receive request, scan nearby towers' information and send it to a client-side application. The gathered data was successfully interpreted by the application producing coordinates to locate the current position of the device.

Compared to other tracking devices, the design was proven to have economic and environmental benefits in terms of hardware components and energy consumption, respectively. It has also been established that the device has considerate advantage when it comes to tracking sustainability and manufacturability.

Chapter 5

RECOMMENDATION

Since the density of cell towers available in the area defines the accuracy of the location, the researchers recommends having at least three or more base stations to utilize the device location and provide more accurate results.

Also, the designer of the system recommends using the device in urban areas rather than rural areas because the accuracy decreases as there are less cell towers in the area.

As for the future researchers, a good accuracy algorithm may also be developed in place of what the current researchers utilized at the time of this writing in hopes of achieving a better result.

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APPENDICES

APPENDIX A

SCHEMATIC DIAGRAM OF THE PROTOTYPE

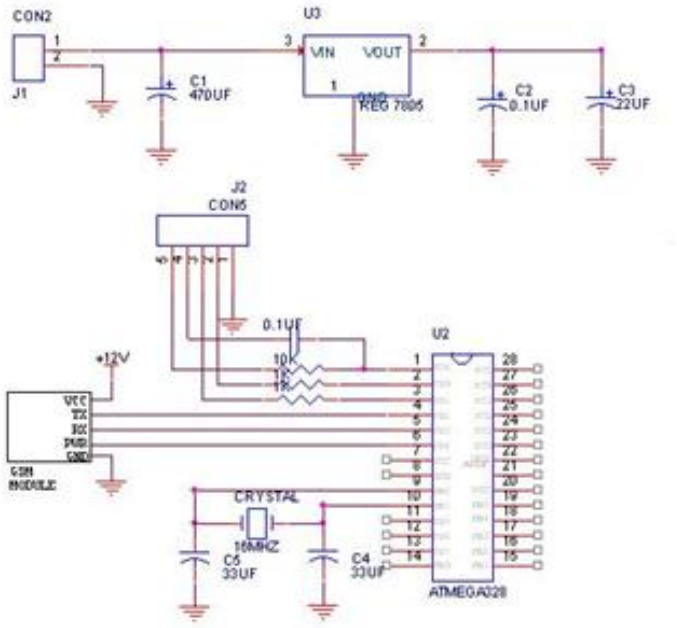


Figure 0.1 Device Schematic

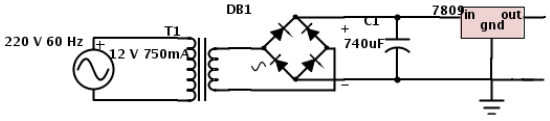


Figure 0.2 Charger Schematic

APPENDIX B

DEVICE PROTOTYPE

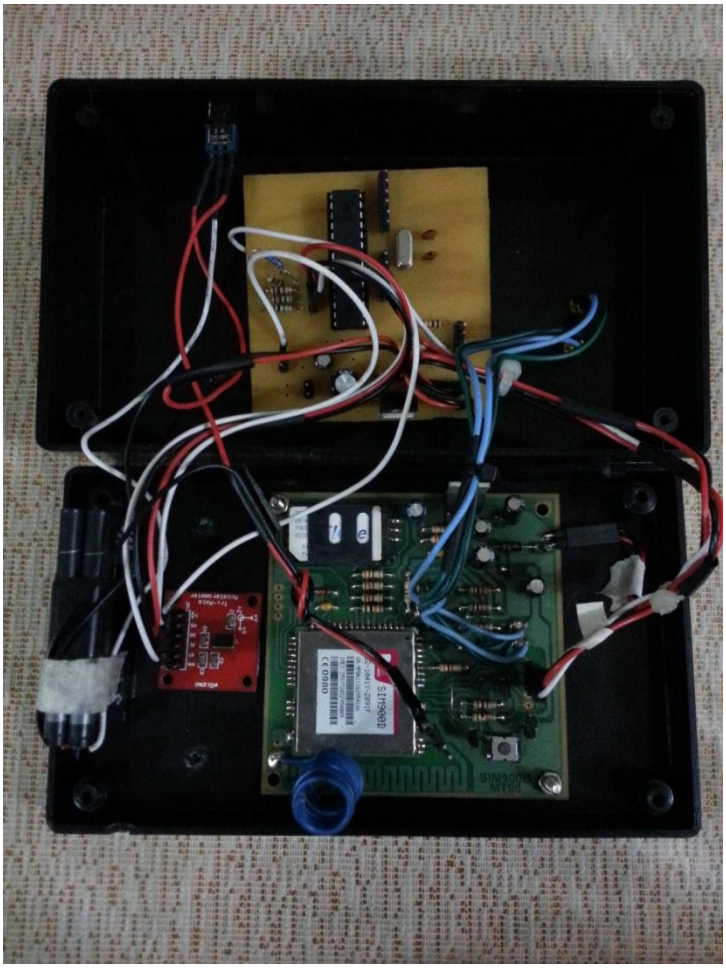
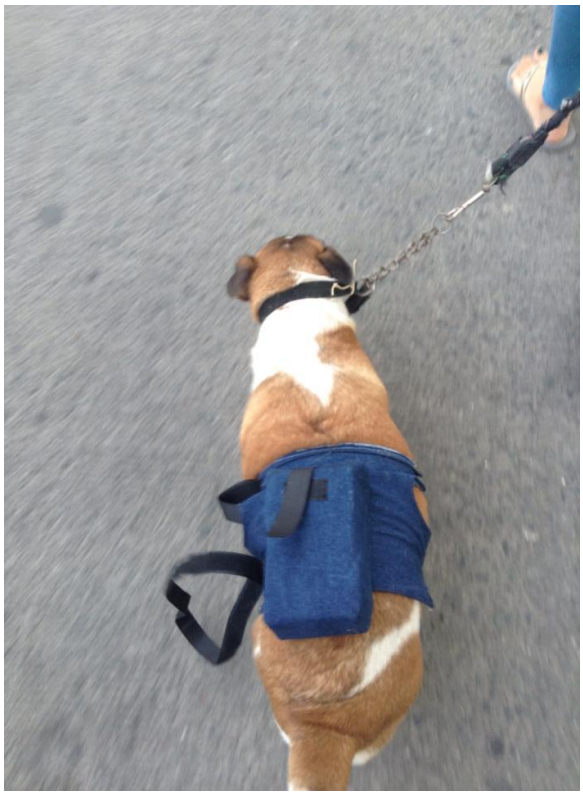


Figure 0.3 Arduino (top), SIM900D (bottom)

APPENDIX C

ACTUAL DEPLOYMENT OF DEVICE

(a)



(b)

Figure 0.4 Device tucked in body strap

APPENDIX D

OPERATION'S MANUAL

System Requirement

Table 0.1 Android Map Requirements

Item	Requirement
Android Version	Minimum: 2.3 (Gingerbread) Supported up to 4.3 (Jelly Bean)
Valid Internet Access	2G to latest or Wi-Fi connection

User's Manual

1 Device
1.1 Operating the device
1.2 Charging the device
1.3 Changing SIM card

2 Android Application
2.1 Installing the application
2.2 Operating the application
2.2.1 Tracking Screen
2.2.2 Changing the settings
2.2.2 Tracking the device

1 DEVICE

1.1 Operating the device

Place the device in a secure location. Make sure it will not fall off or get wet. When ready to use, flick the toggle switch. It will take a minute for the GSM module to initialize. LEDs indicate whether the device is turned on or off. After use, flick the toggle switch to turn the device off. Refer to Figure 6-4 for toggle button's ON and OFF positions.

Figure 0.5: Device ON and OFF State

1.2 Charging the device

When the device is turned on for a long time or when the power of the device is running low, it is advised that the user should turn off the device before plugging in the charger supplied with the device.

Connect the device to the supplied charger making sure the correct polarity is observed as shown in Figure 6-5.

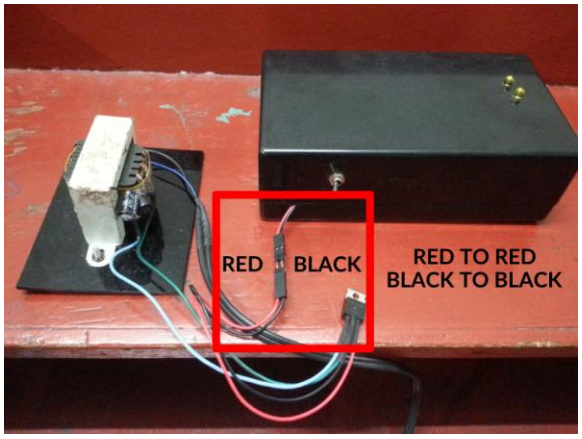


Figure 0.6: Charging the device

1.3 Changing the SIM card

If the user wants to change the SIM card of the device, he/she is advised to follow these steps first:

1. Insert the new SIM card to another device.
2. Create a contact or phonebook entry in **SIM memory** named "**ADMIN**" without the quotations and all capital letters. Use the number of the phone where the supplied Android Application is installed. (Ex. Name – ADMIN Number - 09171234567). See Figure 6-6 for reference.

Figure 0.7: Phonebook entry, ADMIN

3. After saving the phonebook entry, remove the new SIM card from the other device.

Make sure that the device is turned off. Unscrew the screws that secure the GSM module inside the device. If there is a SIM card in the SIM card slot, remove it and replace with the new SIM card. Once placed, put back the cover and secure the device with screws. Refer to Figure 6-7 for the detailed steps.

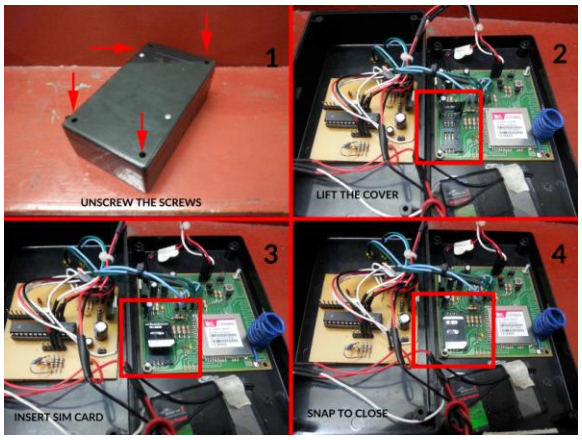


Figure 0.8: Changing the SIM card

2 ANDROID APPLICATION

2.1 Installing the application

1. Navigate to the phone settings and under **Security**, tick a **check** in the box under **Device Administration** that says **Unknown Sources**.

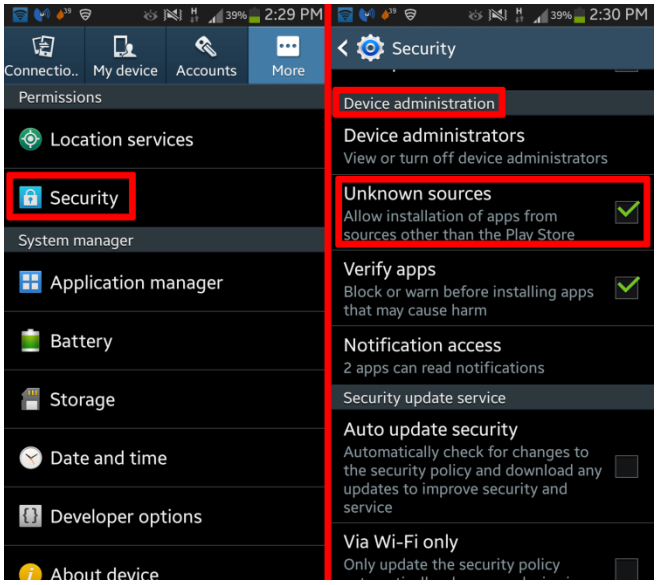


Figure 0.9: Android Settings - Security

The application is not yet publicly released to the official app market hence the user should **Allow installation of apps from sources other than the Play Store** as shown in Figure 6-1.

2. Copy the supplied android application, named **arfcnLocator.apk**, into a preferred directory of choice in the android phone. Check Figure 6-2 below for an example.

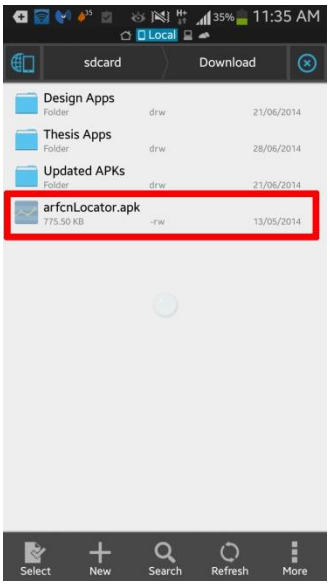


Figure 0.10: Copying apk to directory

3. Choose or tap the file and *follow normal installation procedures* as illustrated in Figure 6-3.

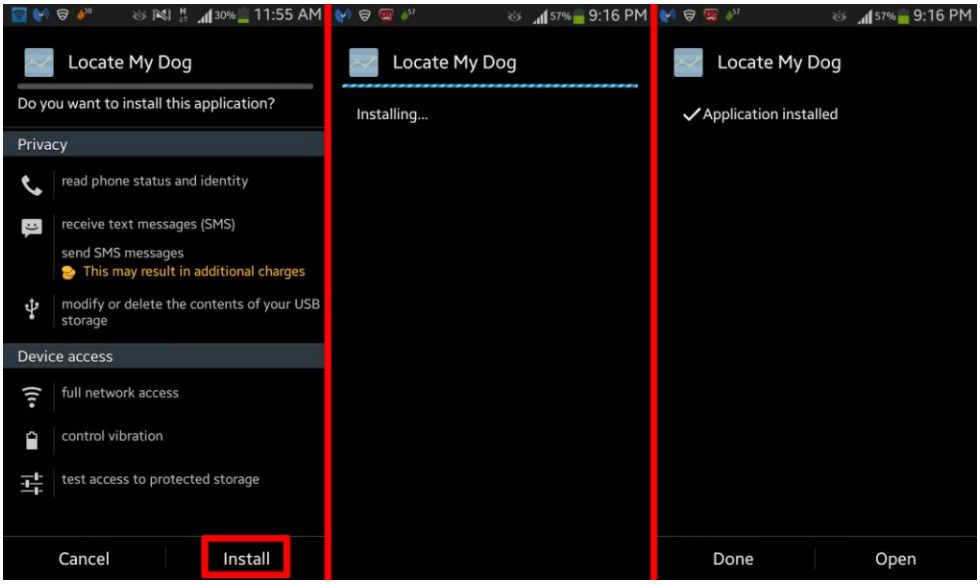


Figure 0.11: Application Installation

The **device** on the other hand should be placed in a **stable surface** such as the car's **dashboard**. Items that may **disrupt reception** should be **kept away** from the **device**.

2.2 Operating the application

When the user wants to use the application, choose or tap the logo of the installed application named **Locate My Dog** as shown by Figure 6-8.

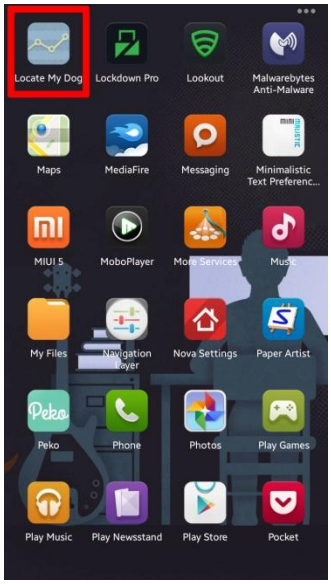


Figure 0.12: Launching the application

2.2.1 Tracking screen

The application will open showing a ***splash screen*** first and then an interface showing several buttons namely ***Track, Settings, Details, Reload,*** as well as ***Forward*** and ***Backward***. Refer to Figure 6-9 for visualization.

a) ***Track*** – sends an SMS message to the device attached on the dog, querying it for location determination. Once an appropriate reply is received, it grabs data (coordinates) on the server and loads the map pinpointing the coordinates obtained from the server.

b) ***Settings*** – used to specify the number of the SIM card which is attached to the device as well as the IP address of the server needed to extract data from.

c) ***Details*** – shows text message details such as the serving and neighboring tower information. An address is also shown when applicable.

d) ***Reload, Forward and Backward*** – used to reload, move forward or backward a page on the map. Acts the same purpose found on common web browsers.

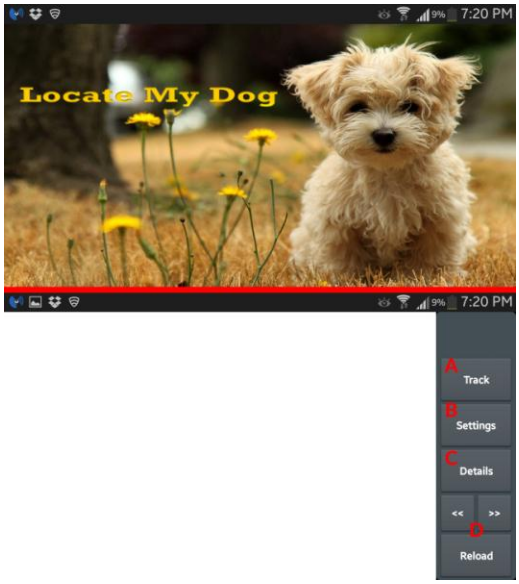


Figure 0.13: Splash Screen (top), UI (bottom)

2.2.2 Changing the settings

Once the ***Settings*** button is pressed, a new window will pop up.

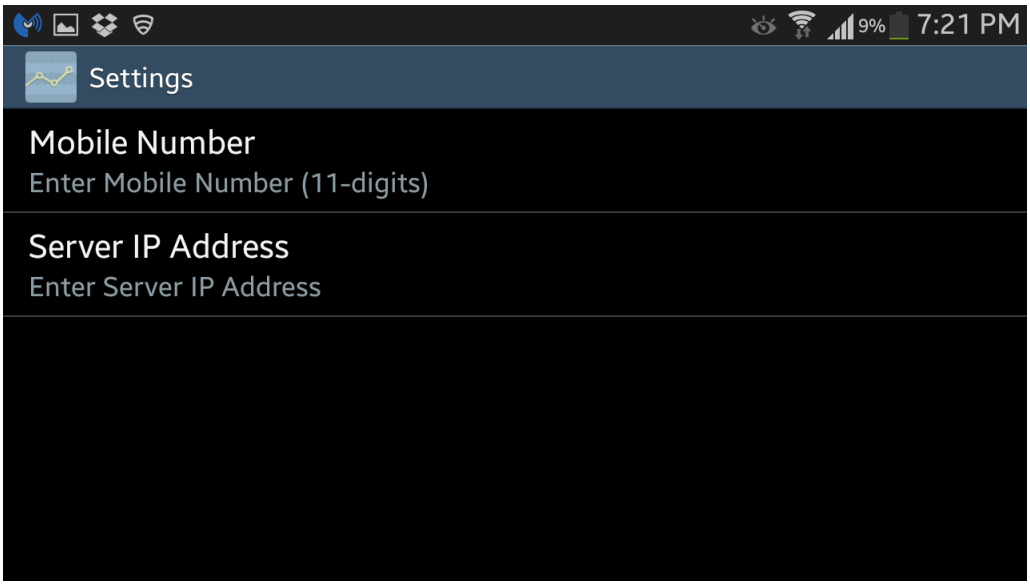


Figure 0.14: Settings Screen

From Figure 6-10, enter the SIM card number in the text box (example: 09191234567) prompted under ***Mobile Number***. A valid mobile number must not exceed or be less than 11-digits. Tracking will not proceed until this rule is observed; this is done to ensure each text message sent is valid and will reach the intended destination. If the user typed a wrong number or wishes to change what has been applied, he/she can re-enter the number.

Specify the ***IP address*** of the server where the data concerning coordinates will be fetched. To know the IP address, go to the host machine and type '***ipconfig'*** in command prompt and find the '***IPv4 Address***'. This is the required ***IP address***. Again, tracking will not commence unless a valid IP address is entered.

When the user is satisfied with the settings, he/she can press the ***hardware back button*** to go back to the tracking screen.

2.2.3 Tracking the device

To track the device, the user must apply the appropriate SIM card number in the settings first. Make sure that the device placed on the dog is turned ON and both the device and the android mobile phone have sufficient load balance. Just press ***Track*** and observe the onscreen prompts and wait until the map is loaded. See Figure 6-9 for reference of button positions.

Troubleshooting Guides and Procedures

1. **Device does not turn ON or stopped working.**

Make sure the battery is fully charged and the switch is flicked to ON state. The LEDs will indicate if there is power.

2. **No message received from the android application.**

Try **resetting** the device, to do this flick the switch to **OFF** state then turn it back **ON**. Let the device settle in a minute before querying it again via the android application. Make sure there is **SIM inserted** on the device and both device and mobile phone should have **prepaid balance** beforehand. If the device is unavailable, try pressing the track button again per 5-minute intervals until a reply is received.

3. **Map does not load.**

This is a common problem on a **slow internet connection**. Just wait until it properly loads the map.

4. **App crashes upon trying to load the map.**

Most likely the area visited has **no database information** yet. This is normal and the only solution is to **upload measures** of cell data from the concerned location.